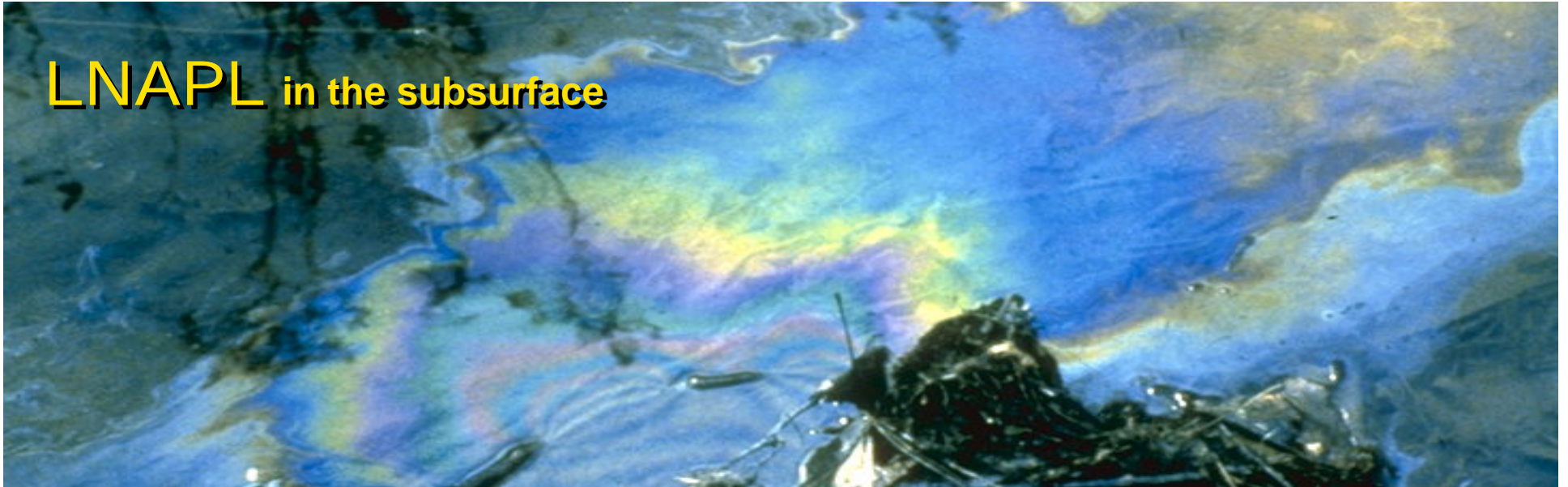


LNAPL in the subsurface



LNAPL metrics



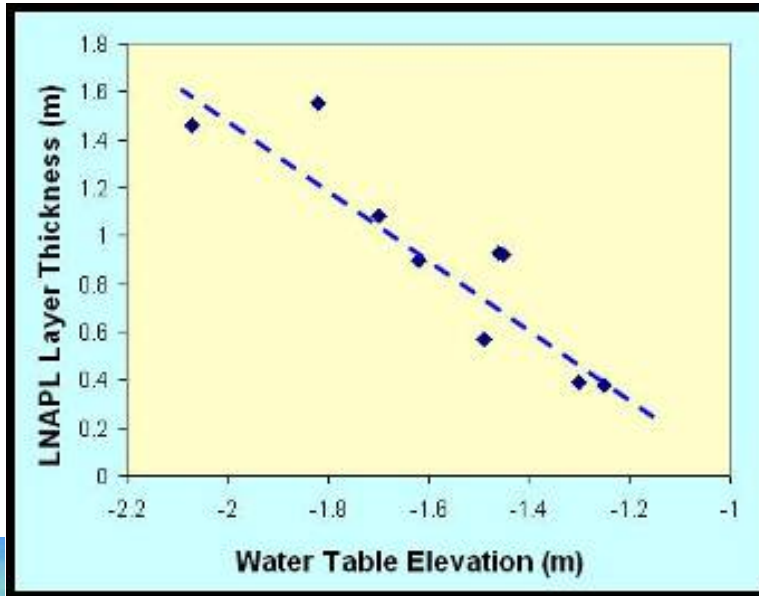
Randall Charbeneau, P.E.
Professor of Civil Engineering, University of Texas

&

Mark Adamski, P.G.
Technical Specialist and Environmental Business Manager, BP America



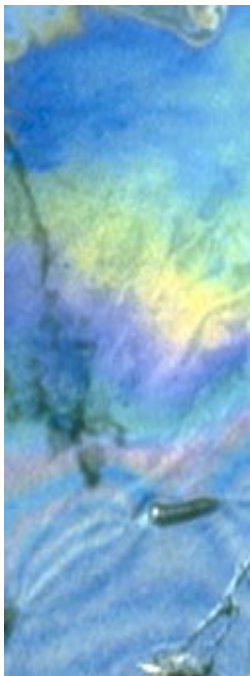
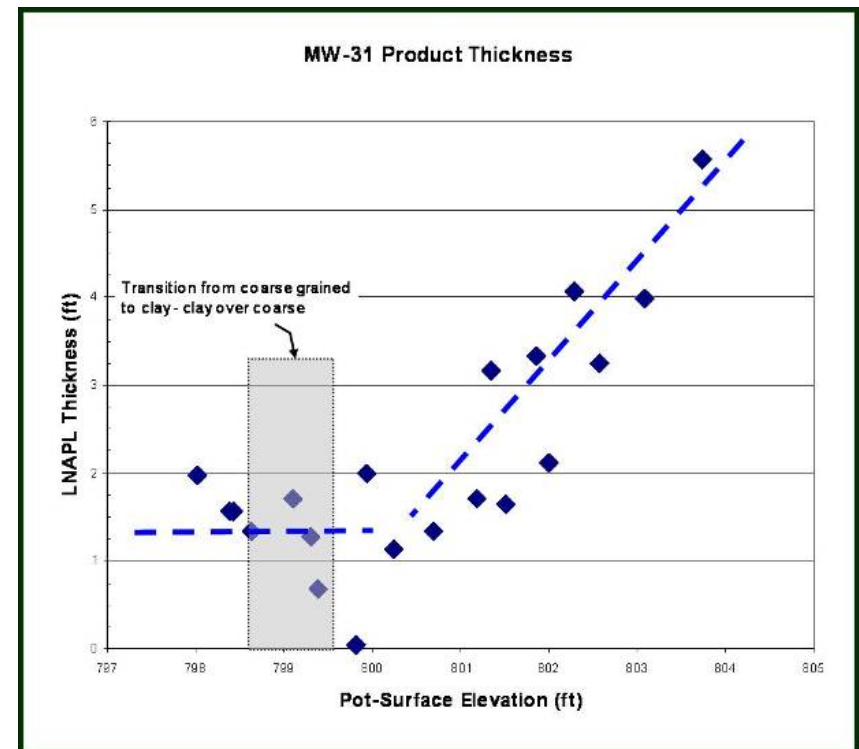
LNAPL thickness varies without change in LNAPL volume in the ground



Classical behavior (unconfined system) between Water Table Elevation and LNAPL Layer Thickness in a Monitoring Well

Figure from Charbeneau (2005)

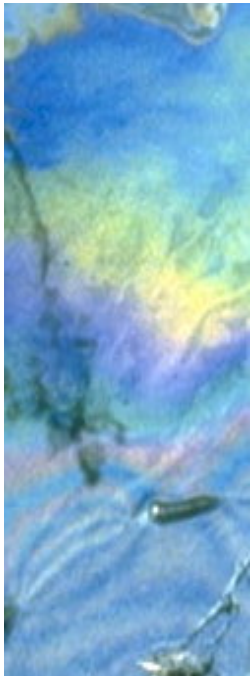
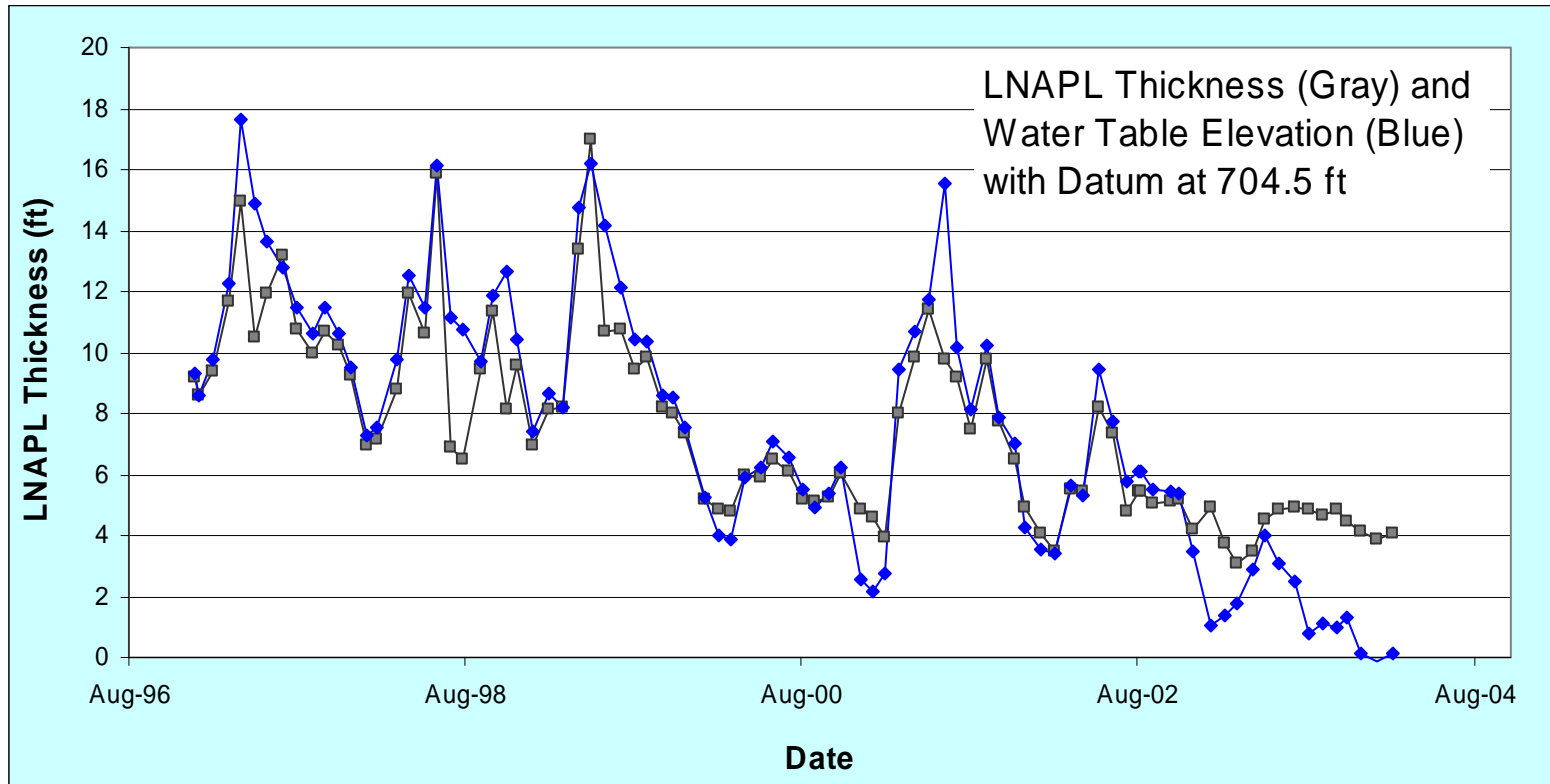
Confined LNAPL behavior between Water Table Elevation and LNAPL Layer Thickness in a Monitoring Well



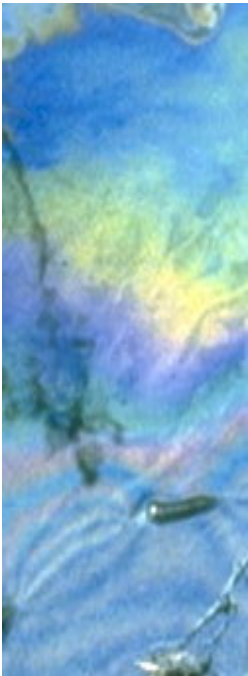
LNAPL in the subsurface



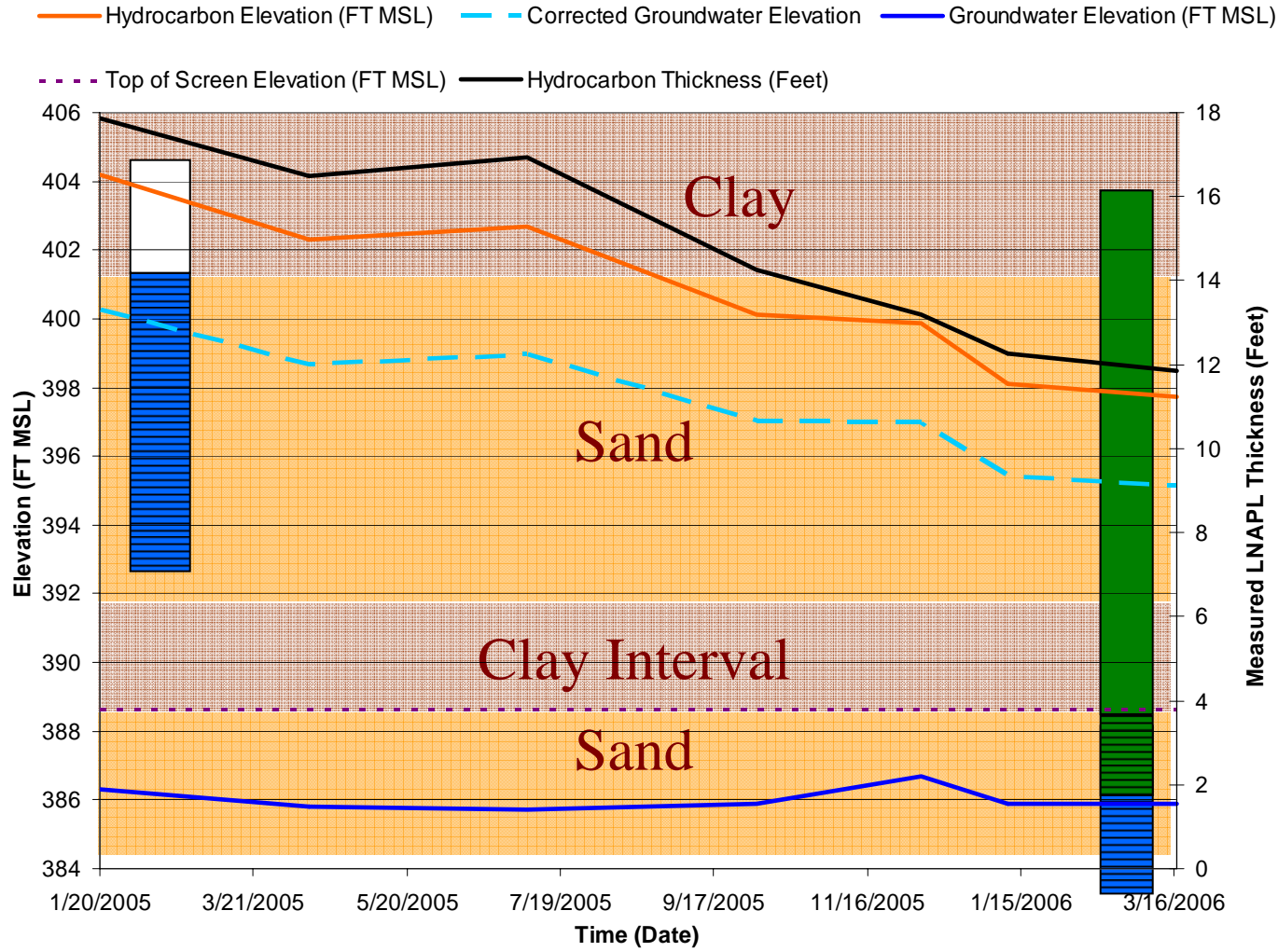
Another example of LNAPL thickness variation



LNAPL in the subsurface



Hydrograph - Confined LNAPL



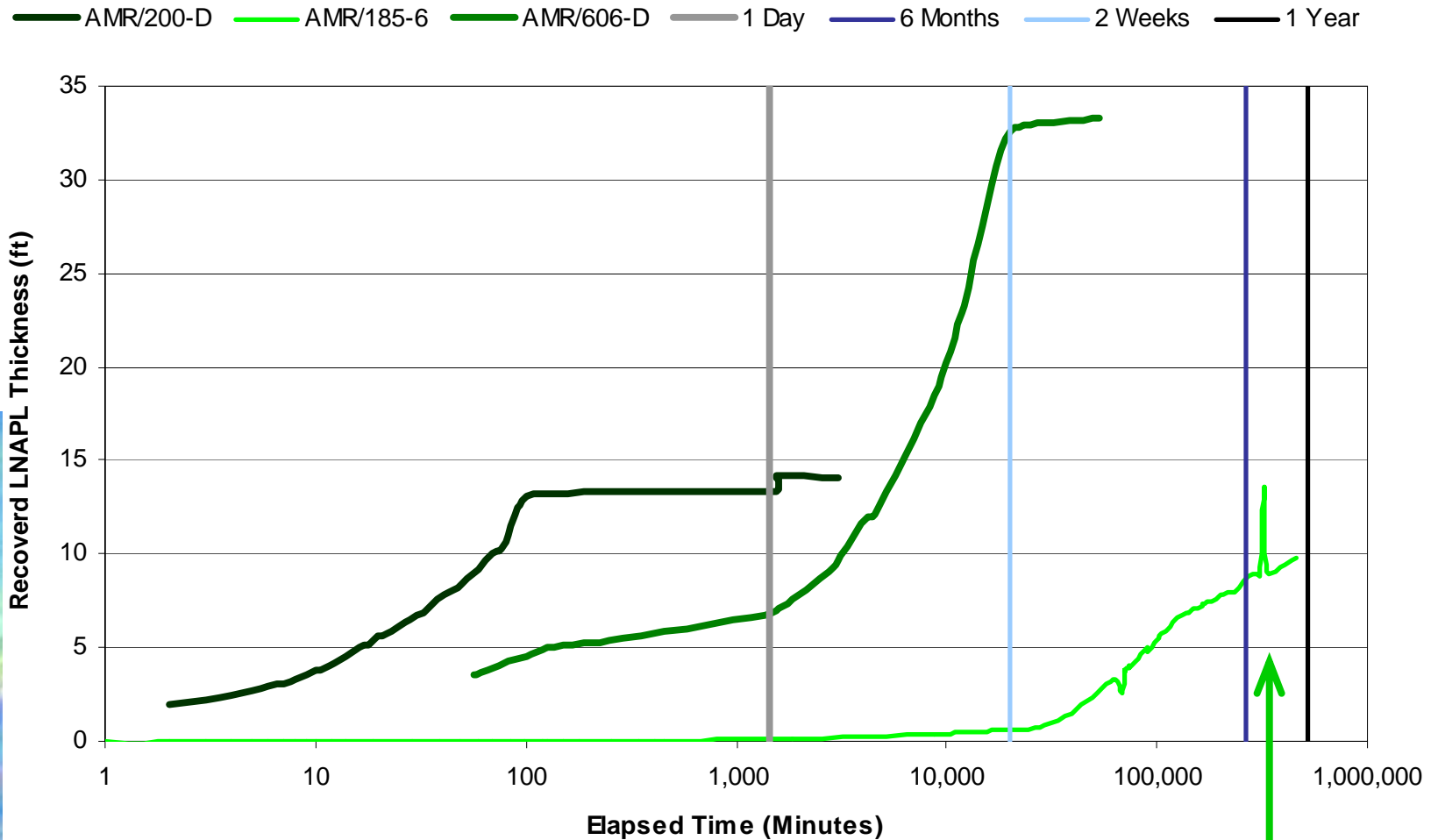
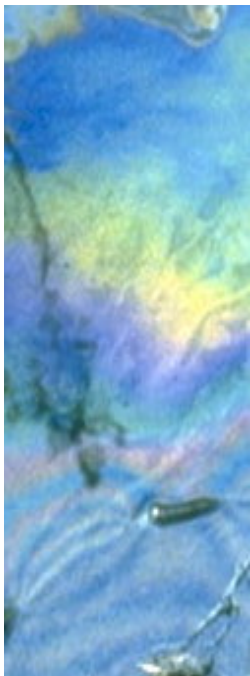
LNAPL in the subsurface

Courtesy of Andrew Kirkman



LNAPL Thickness and Recovery Time

(Three real examples)

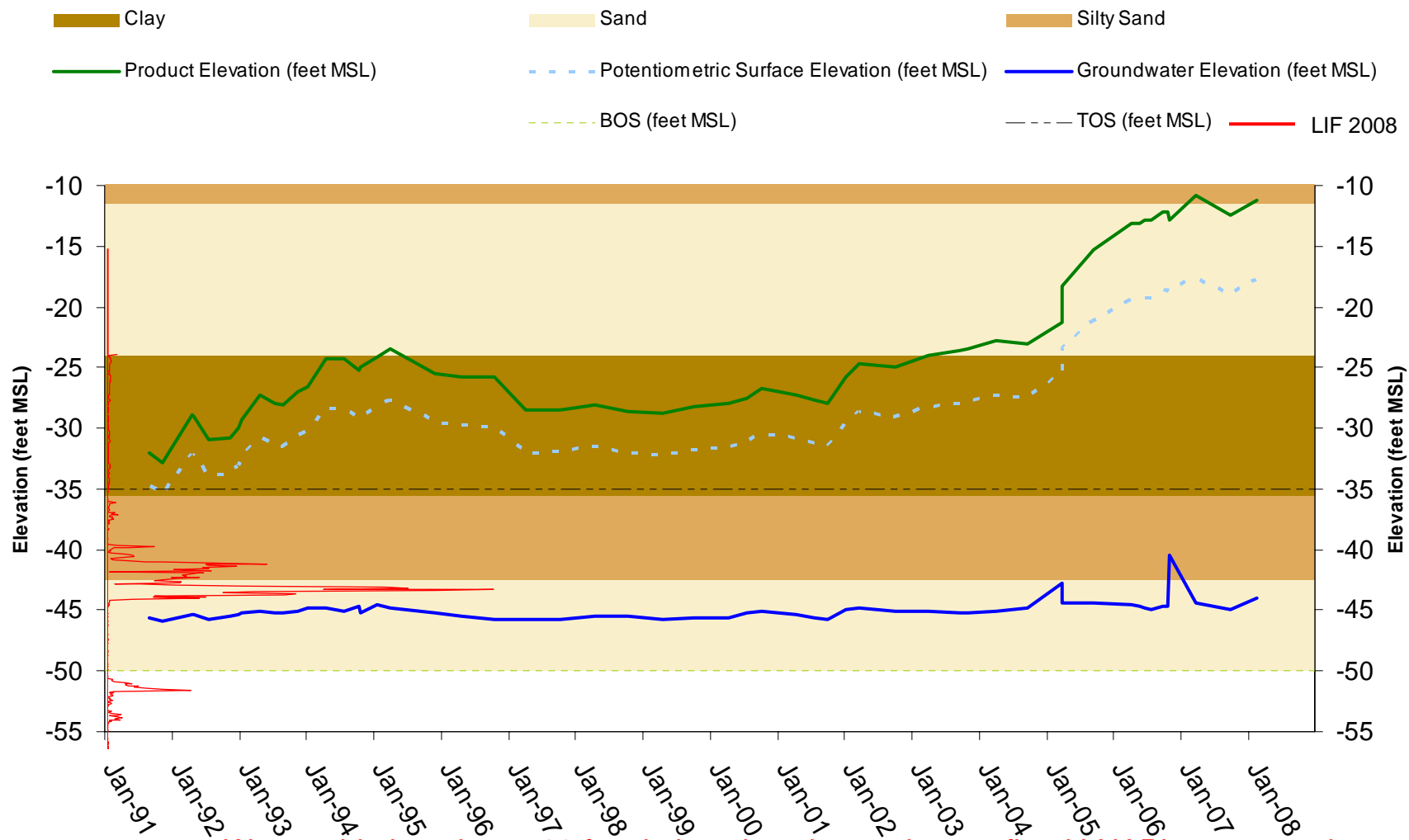


Still Recovering,
Expected to Ultimately
Reach ~30 ft



AMR/606-D Hydrograph (well from previous slide)

AMR/606-D Hydrograph

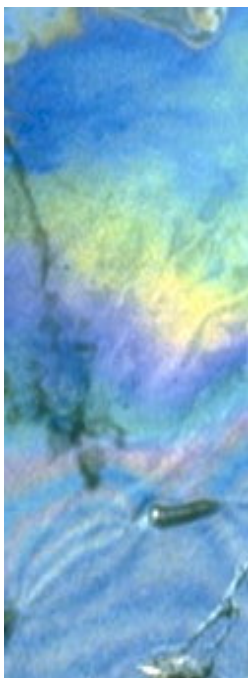


Water table has risen ~20 feet in last decade causing confined LNAPL to accumulate to large thickness in the well – would still recover like a well with ~ 2 – 3 ft of LNAPL



LNAPL Transmissivities and Thicknesses

Location	Approximate Gauged Thickness (ft)	Recovery Rate Based on Baildown Test Data		LNAPL Transmissivity (ft ² /day)
		LNAPL Skimming (GPD)	1 GPM - Water Enhanced Recovery (GPD)	
AMR/200-D	15	40	115	4
AMR/185-6	30	0.4	0.7	0.01
AMR/606-D	34	2	5.7	0.2



- LNAPL thickness is no indication of LNAPL recoverability
- LNAPL thickness, in this case, is no indicator of additional LNAPL in the subsurface

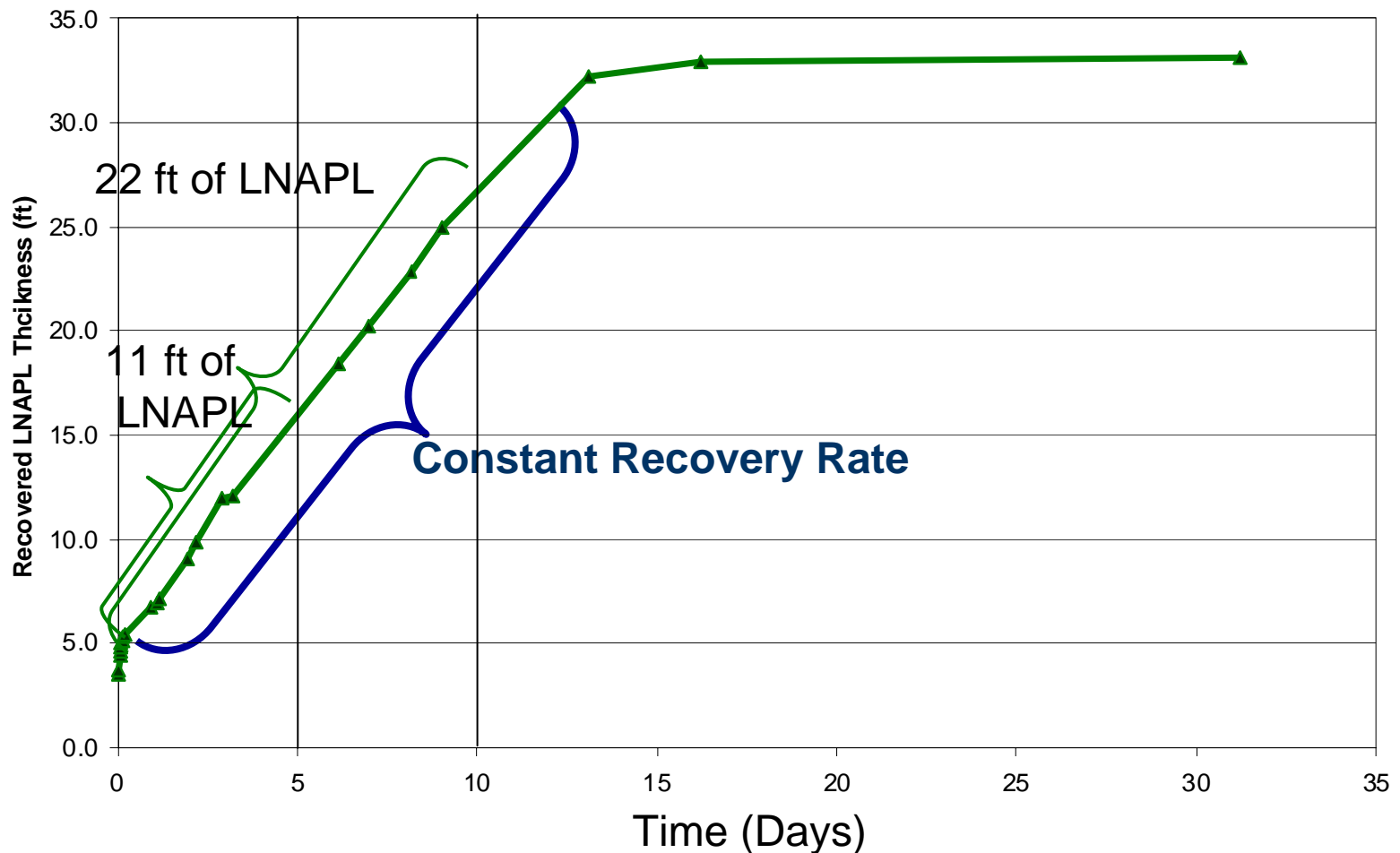
LNAPL in the subsurface



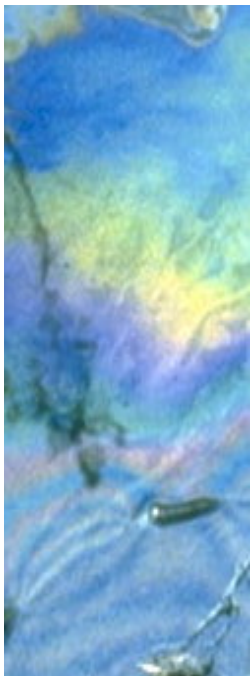
Recovery Prior to Equilibrium Doesn't Increase Production

Recovering from the well every 5 days doesn't produce more over an extend period than recovering every 10 or 12 days

Gauged Recovery of LNAPL Thickness



LNAPL in the subsurface





LNAPL Metrics



LNAPL Thickness

- Inconsistent between hydraulic scenarios
- Inconsistent between soil types

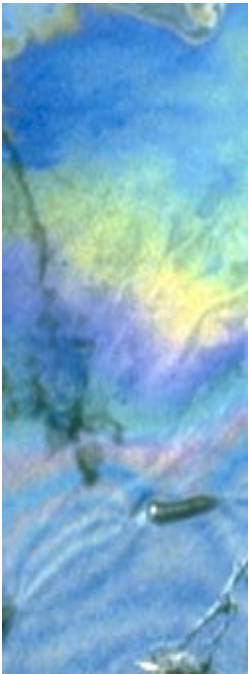
LNAPL Recovery Rate

- More Robust Metric than LNAPL Thickness
- Need recovery system or pilot test data
- Operational variability and technology differences make it difficult to use across technologies and/or sites

Transmissivity

- Most universal (site and condition independent)
- Estimated with recovery data or field testing on monitoring wells
- Consistent across soil types
- Consistent between recovery technologies
- Consistent across confined, unconfined or perched conditions

Transmissivity provides a consistent measure of recoverability and impacts across different LNAPL plumes within one site or across multiple sites



LNAPL in the subsurface



Example LNAPL Evaluation

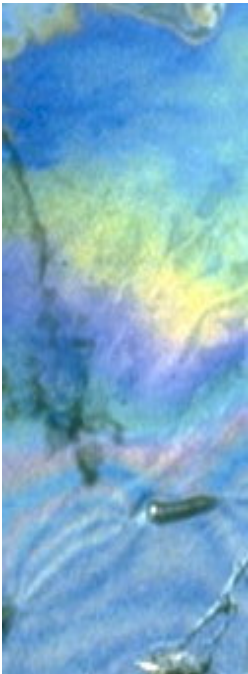


Distribution of LNAPL

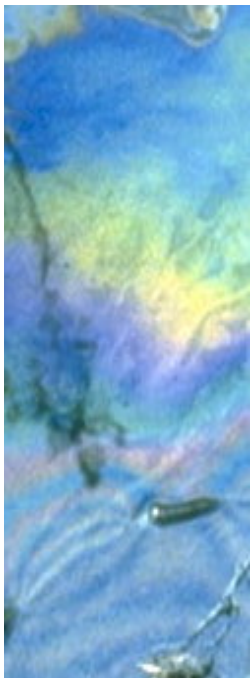
- LNAPL analytical samples
- CPT/ROST borings
- Core borings submitted to geotechnical lab

Results Included

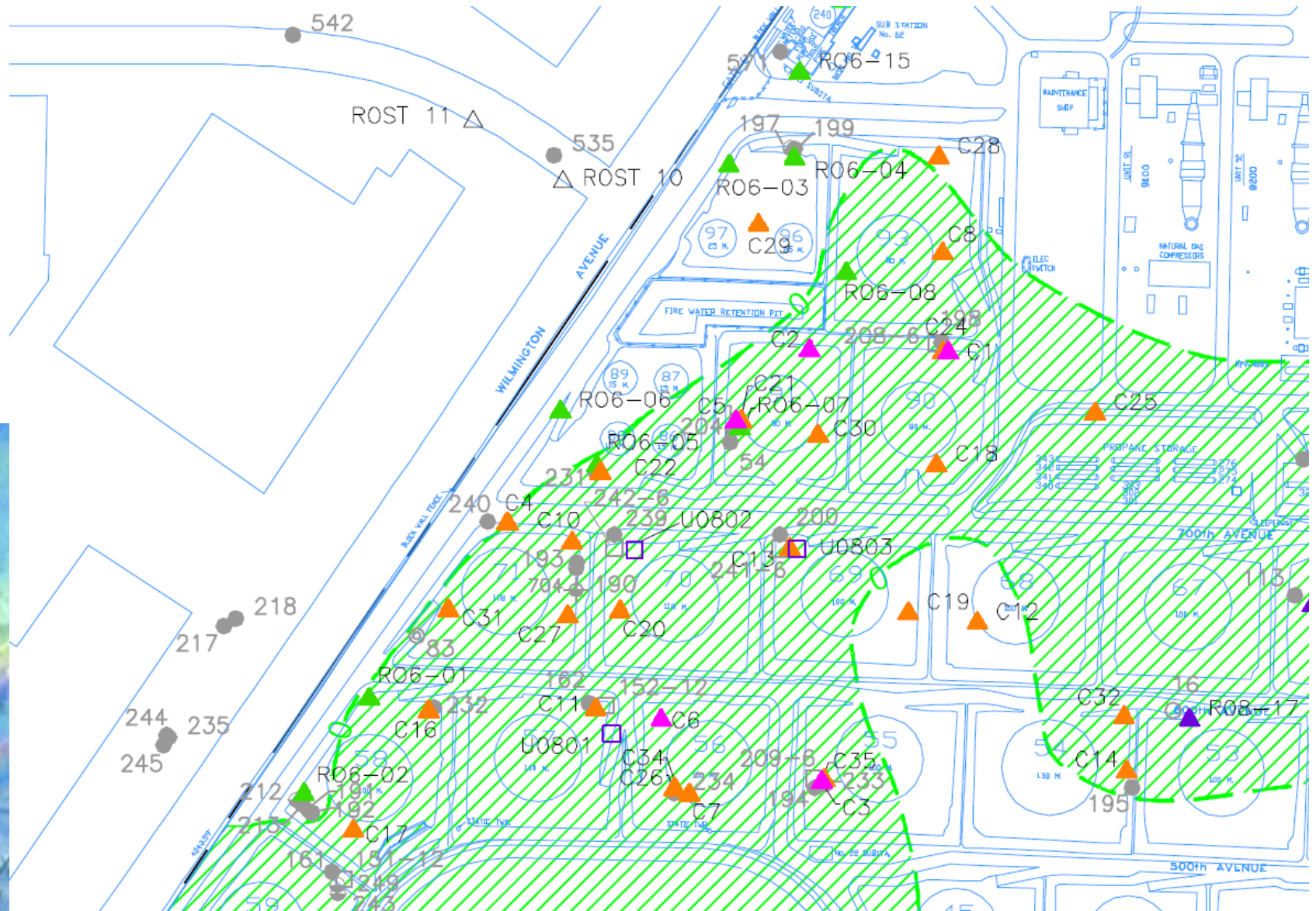
- Calculated mobility (i.e Transmissivity)
- Improved understanding of LNAPL distribution



LNAPL in the subsurface



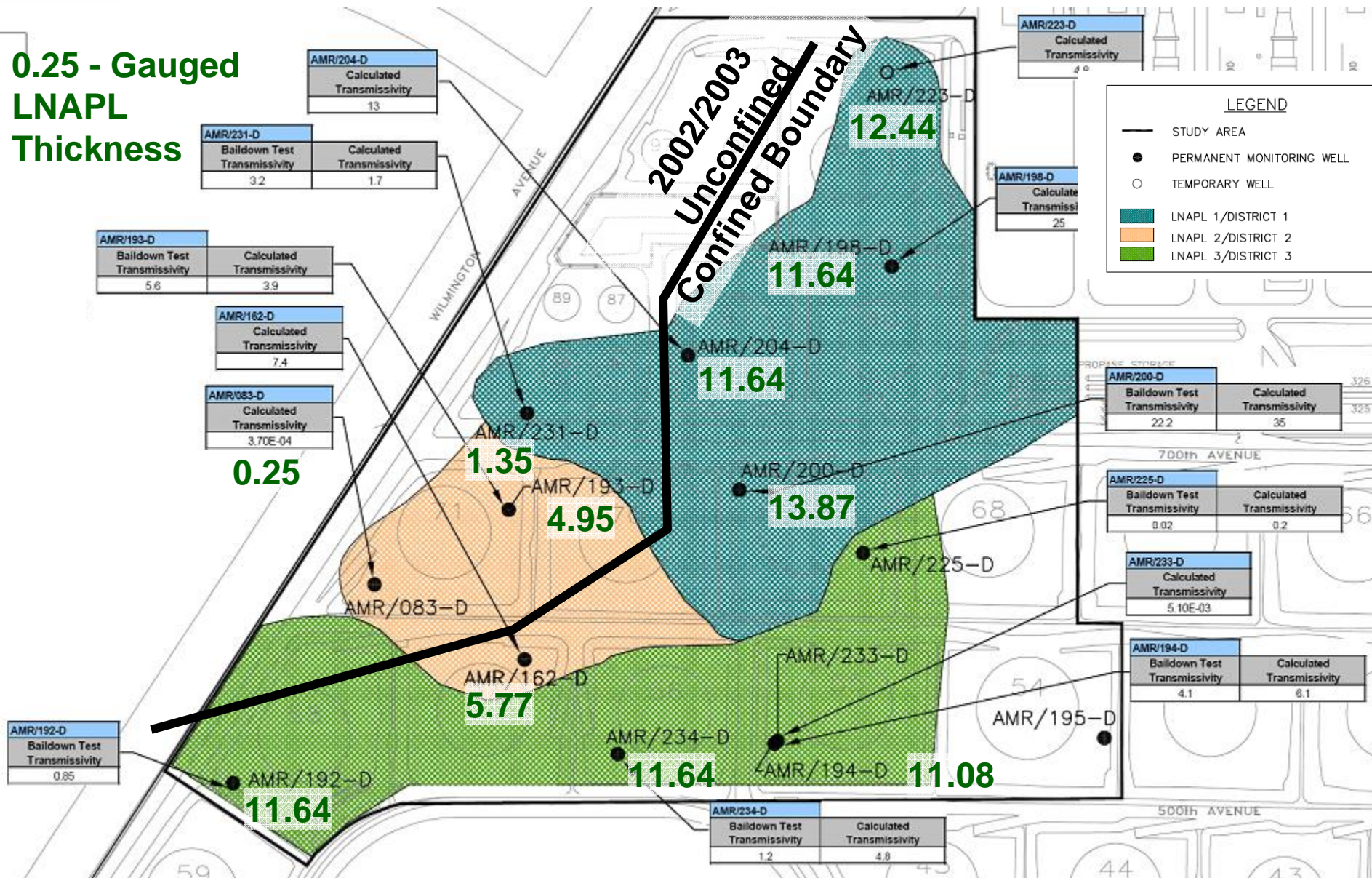
Study Area Assessment (ROST borings)





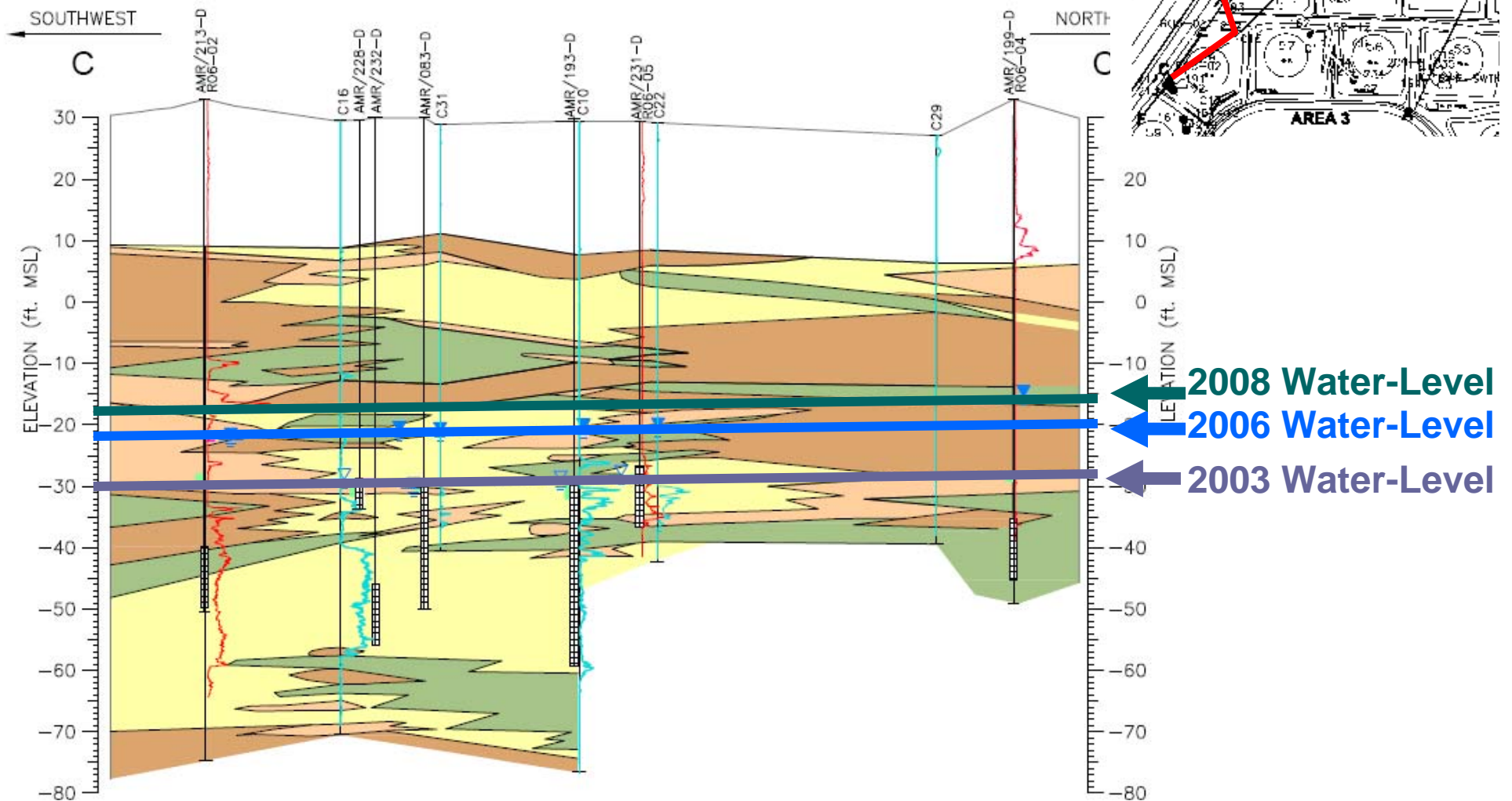
2003 LNAPL Distribution

0.25 - Gauged
LNAPL
Thickness





Rise in Water Level Causing Confined Conditions Across Study Area





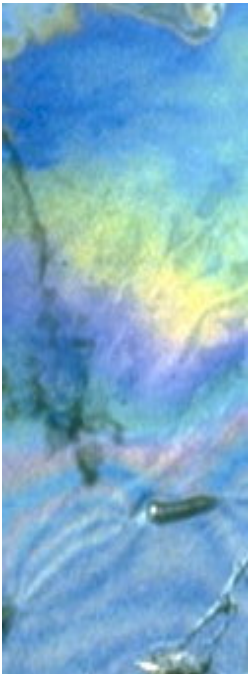
2002-2003 LNAPL Evaluation Summary

Based on Assessment in 2003

- LNAPL type varied from light end of gasoline to heavier gas oil range
- LNAPL existed within varying soil types
- Confined and unconfined conditions existed
- Gauged LNAPL thickness not indicative of LNAPL recoverability

Transmissivity identified as best metric - it accounts for:

- Soil types
- LNAPL types
- Hydrogeologic conditions



LNAPL in the subsurface

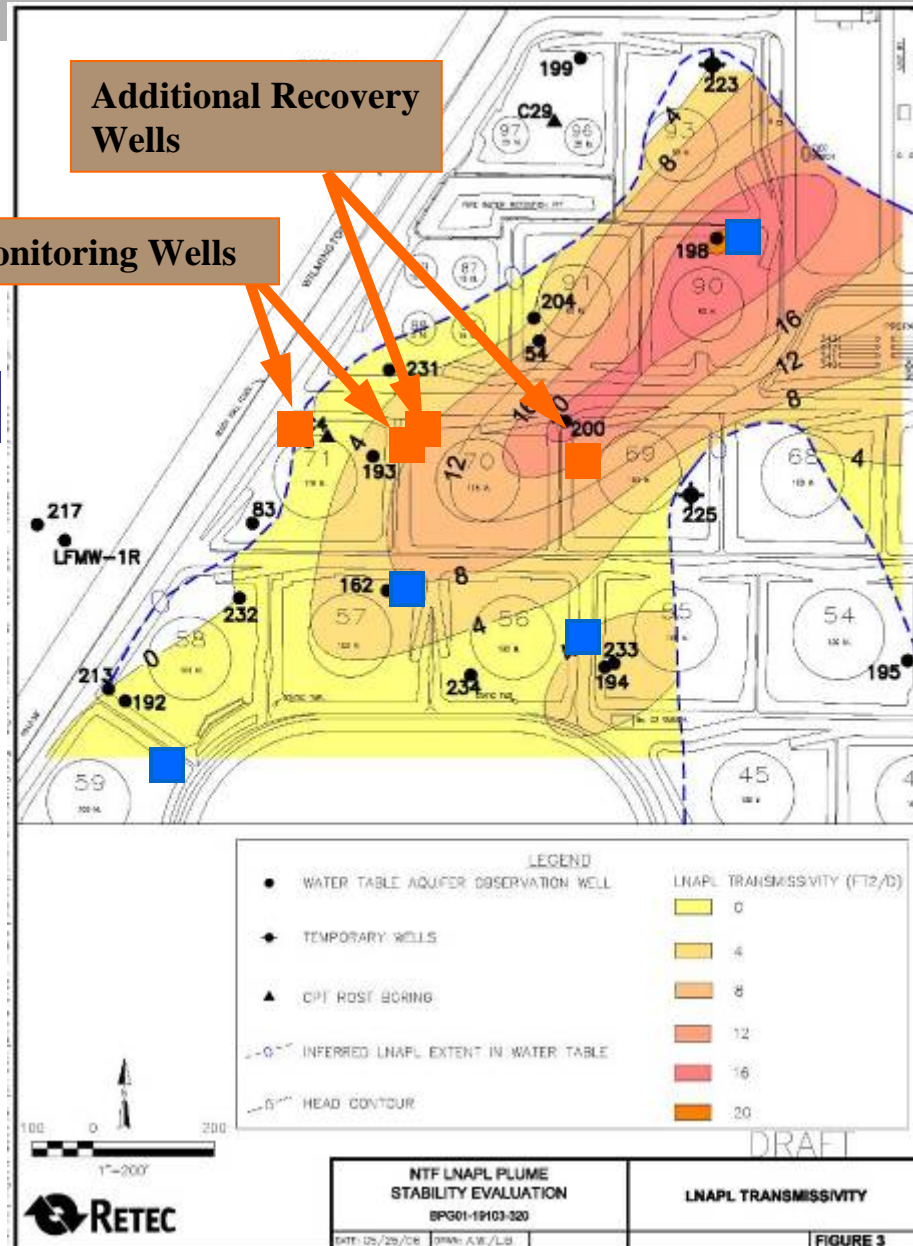


LNAPL Transmissivity (2003)

■ — Existing Recovery Well

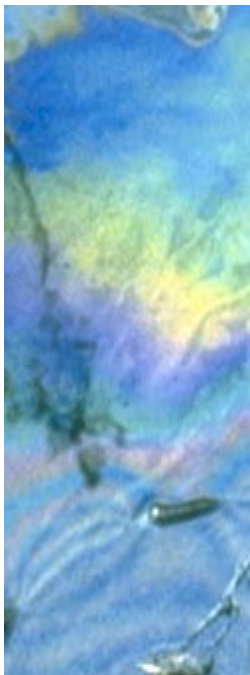
Additional Monitoring Wells

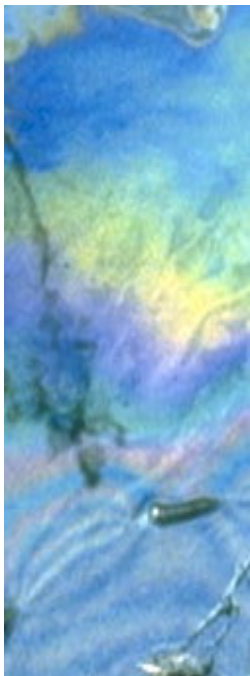
Additional Recovery Wells



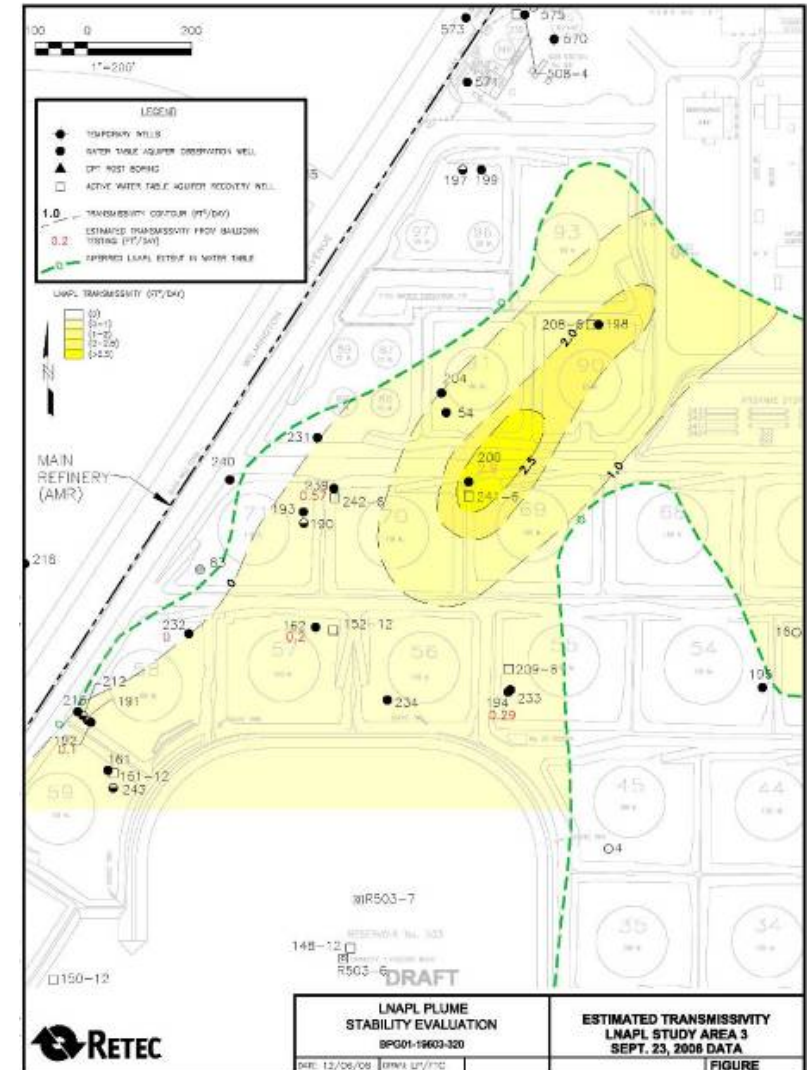
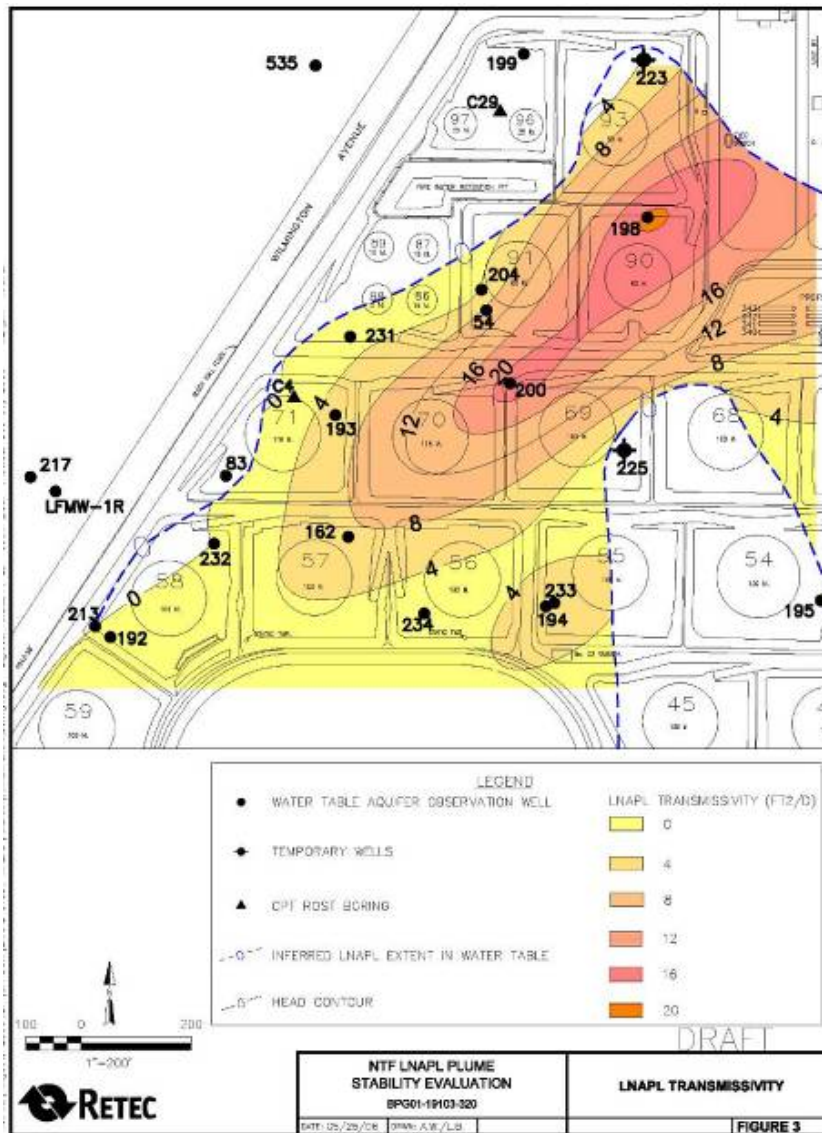
(Transmissivity ft²/day)

LNAPL in the subsurface





2003 to 2006 Comparison - LNAPL Transmissivity



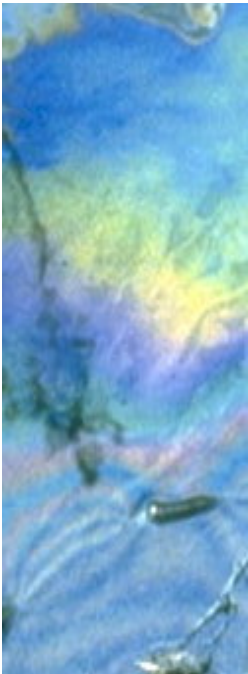
LNAPL in the subsurface



Key Points



- LNAPL thickness is a very poor LNAPL metric due to variations without changes in LNAPL volume
- LNAPL recovery rate is a good metric, but requires the data from well designed and maintained recovery system
- Transmissivity is a very useful metric for LNAPL decision making



LNAPL in the subsurface



bp



Thank You

LNAPL in the subsurface